DOCUMENT RESUME

ED 221 548 TM 820 556

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TITLE Developmental Changes in the Induction of Semantic Relations.
PUB DATE Mar 82
NOTE 18p.; Paper presented at the Annual Meeting of the American Educational Research Association (66th, New York, NY, March 19-23, 1982).

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Adults; *Age Differences; *Classification; *Cognitive Processes; Elementary Education; Elementary School Students; *Induction; Language Acquisition; Language Processing; Language Research; Semantics

ABSTRACT

Relational-inference, a process associated with developmental change in performance on classification items, was investigated in two experiments. The accuracy and latency with which 20 subjects at each of 3 age levels (8, 11, and adult) stated relationships among concepts were tested. In experiment 1, 40 triplets of concepts related by a class rule and 40 by a property rule were presented. Eight-year-olds were slower and less accurate than the 11-year-olds and adults, especially on property rule items. Experiment 2 explored semantic memory search processes in more detail by examining the hypothesis that the inference process would be negatively affected if an initial inference for a pair of terms had to be revised when a third term was added. Items reflecting five types of class and property rule combinations were examined. Revision items required more time than nonrevision at all age levels. Accuracy varied across ages and type of rule revision. When similar nodes and links exist, developmental differences are associated with the efficiency of activation and retrieval processes, with the effects of path activation on the subsequent activation of competing paths, and with changes in the contents of the network. (Author/PN)

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Developmental Changes in the Induction of Semantic Relations

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Abstract

Relational-inference, a process associated with developmental change in performance on classification items, was investigated in two experiments. The accuracy and latency with which 20 subjects at each of three age levels (8, 11, & adult) stated relationships among concepts were tested. In Experiment 1, 40 triplets of concepts related by a class rule and 40 by a property rule were presented. Eight-year olds were slower and less accurate than the 11-year olds and adults, especially on property rule items. Experiment 2 explored sementic memory search processes in more detail by examining the hypothesis that the inference process would be negatively affected if an initial inference for a pair of terms had to be revised when a third term was added. Items reflecting five types of class and property rule combinations were examined. Revision items required more time than nonrevision at all age levels. Accuracy varied across ages and type of rule revision. Results are discussed in terms of developmental changes in the efficiency of activation and retrieval processes as well as in the contents of semantic memory.

Developmental Changes in the Induction

of Semantic Relations

Mary A. Lairon, Susan R. Goldman and James W. Pellegrino

The ability to reason by induction is a major aspect of cognition. Classification tasks are frequently used to assess inductive reasoning. However, relatively little research has focused on the cognitive processes and knowledge involved in solving such items. Parseghian and Pellegrino (1980) conducted an initial investigation of verbal classification performance. Using a component process approach, they examined developmental and individual differences in solution accuracy. The present research focuses on the component process that was found to be the most important predictor of individual differences: relational inference.

Inference in a typical classification item involves determining an overlap relation for the concepts in the item. Table 1 shows such an item. Given the three stem terms dog, ant, and robin a common relation must be inferred. In this case, the superordinate animal represents an overlapping relation--a node in semantic memory to which each concept is linked. Of the alternatives, alternative four, frog, is also linked to the animal node and is therefore the correct answer. In the Parseghian and Pellegrino (1980) study, children were asked to state an initial inferred relation among the stem terms before the alternatives were presented. The accuracy of this initial inference was the best predictor of solution accuracy. Parseghian and Pellegrino (1980) also found that items where the initial inference was a class membership relation were easier than items where the initial inference involved properties common to the concepts.

Insert Table 1 about here

The present paper reports two experiments that examine the nature of this inference process in detail. The work represents an attempt to "unpack" a component process in classification tasks. In the first experiment we examined the speed and accuracy of inferring relations among sets of concepts that shared either common class membership or common properties.

Previous work in the area of semantic memory organization and retrieval provided the basis for our predictions and selection of specific class and property rules used in the first experiment. Our general prediction was that class rules would be easier and faster than property rules. This is consistent with previous findings that adults more quickly verify superordinate than property relations (e.g., Collins & Quillian, 1969; Conrad, 1972) and with the results of Parseghian and Pellegrino (1980). From a developmental perspective, we anticipated that the difference between class and property rules would be smaller in younger children. This prediction was based on assumptions about the development of semantic memory and its organization. Nelson's (1979) work on concept formation and changes in the organization of semantic memory indicates that class relations appear to be established quite early for familiar and common categories, e.g., animals and colors. She also places strong emphasis on the role of function information in the formation of concepts and assigns a secondary role to perceptual features. Thus, we expected to find differences between function and perceptual property rules.

Twenty subjects at each of three age levels--8, 11 and adults--were asked to state a relation for each of 80 items. Accuracy and response latency were measured. Each of the 80 items contained three concepts. Half of these represented class and half property rules. In addition, 4

types of classes and 4 types of properties were represented. The four classes were animals, plants, manmade objects and naturally occurring phenomena. The latter included colors, geographical formations, and weather. The four types of property rules represented three kinds of perceptual features shape, texture, size. The fourth property was function. Concepts were selected so that vocabulary was within third grade reading range.

Analyses of both accuracy and latency for correct responses indicated main effects of age: the 8 year olds were less accurate and slower than the 11 year olds and adults who did not differ from one another. Table 2 shows the accuracy and latency results for the class versus property rules. The accuracy data indicate that class rule accuracy increases faster than property rule accuracy: the 11 year olds are significantly more accurate on class versus property rules while accuracy is equivalent on the two types of rules for the adults. Accuracy is also equivalent for the 8 year olds but at a lower level. Essentially, the accuracy data support a gradual developmental trend in the ability to infer property rules and a more rapid shift to asymptotic levels of performance on class rules.

Insert Table 2 about here

The latency data supports the general prediction that class rules are faster than property rules. This was true for each age group. However the magnitude of the difference between class and property rules <u>decreased</u> across ages. This was unexpected. More detailed examination of the data did support our original prediction. Contrasts were conducted among the four types of class and four types of property items. None were signifi-

cant for the 11 year old and adult subjects. However, there were significant contrasts for the 8 year olds and these are consistent with two predictions based on Nelson's work. As shown in Table 2, within class rules, the two more familiar subgroups, i.e., animals and naturally occurring phenomena, were faster than the others. This supports the notion that superordinate-subordinate relations for common categories are established earlier and/or more firmly than for less common categories. In addition, within property, function rules were faster than perceptual attribute rules. This supports the notion of the primacy of function over other types of properties.

The results of this experiment indicate that by 8 years old there is a relatively well-established network of concepts. Links from concepts to superordinates as well as concepts to properties are established. However, the strength of the links varies with the specific category and the specific property. The major developmental differences appear to lie in the efficiency of the processes involved in searching semantic memory. Experiment 2 explored these search processes in more detail. Predictions and conditions were based primarily on spreading-activation models of search and retrieval (e.g., Collins & Loftus, 1975). The general claim examined in Experiment 2 was that the inference process ought to be adversely affected if an initial overlap relation must be revised. That is, if your first idea of the overlap relation among a set of terms does not apply to an additional term, a new overlap relation must be determined. This revision should take longer than if an additional term is consistent with the original overlap relation.

Five types of items were presented to 20 subjects at each of three age levels: 8, 11, and adults. The five types of items are shown in Table 3:

Class to Class rule, Property to Property rule, Class to Higher Class rule, Class to Property rule, and Property to Different Property rule. Each item consisted of a triplet of concepts. However, subjects first saw a pair and stated a relation; then the third concept was added and again subjects were asked for a common relation. For the C-C and P-P items, the rule for the pair was also applicable for the triple. No revision of the inference was necessary. However, the other three types of items all involve some type of revision. In the C-P condition, the pair rule was a class rule, e.g., animals, but the addition of the third term required a property rule.

Insert Table 3 about here

We had three general predictions, all of which were supported. First, based on the results of Experiment 1, we expected class rules for pairs to be faster than property rules for pairs. The data in Table 4 show that this was the case for each age group. Second, inference latency for the triplet was expected to be longer when revision was required. This was also the case for each age group. Finally, based on the results of Experiment 1, we expected the overall latency differences among age groups which are illustrated in Table 4, but no differential effects of the conditions.

Insert Table 4 about here

The obtained latency patterns across the various item types have implications for patterns of path activation in a spreading-activation model. Figure 1 depicts these patterns as well as the triplet latency for

each age group on each item type. Solid lines refer to links between nodes that are fully activated when a response is made while dotted lines represent links that are partially activated. In the C-C case, A and B are the terms in the pair. When presented, activation spreads throughout the network and a superordinate node intersection occurs before a property node intersection. When C, the third term comes along, A, B and their superordinate are still partially activated and activation from node C intersects with the previously activated superordinate node. This is contrasted with the Class-Higher Class case. In this case activation from node C does not intersect with the node activated by the intersection of A and B. Activation must continue to spread until a common node of intersection is reached. A similar analysis holds for the P-P and P-DP cases, with the exception that superordinate class nodes are also activated during property intersection searches. Finally the C-P case is rather interesting. This type of revision adds less time than the P-DP revision. There are two possible reasons for this. When the class rule for the pair is inferred, properties of the pair terms will be partially activated. When the third term comes in, an intersecting property node is already in a partial state of activation. In the P-DP case, the activation of a common property node for the pair may actually dampen links to other property nodes. When the third term comes in, activation of an intersecting property node for all three terms takes longer than when property links had only been partially activated.

Insert Figure 1 about here

This analysis is consistent with the obtained latency patterns in each

age group. It thus appears that the locus of developmental change resides in the speed of activation and intersection, a change in efficiency. This is the appropriate conclusion with one major caveat: It holds only for items on which subjects actually get the correct answer. There were in fact developmental differences in the accuracy rates for the different item types. These differences implicate organizational and content factors as additional sources of developmental change in semantic inference. The accuracy patterns for the revision conditions are of particular interest. These data are shown in Table 5. For the Class to Higher Class rule, accuracy improves as age increases. The dominant response error was giving the higher class rule for the pair. Thus, for the children errors were largely due to the absence of an intersecting mid-range superordinate, e.g., fish or birds. This phenomenon is consistent with other developmental evidence showing that general class terms like animal are acquired prior to subclasses of animals. The other two conditions, Class to Property and Property to Different Property, created problems only for the youngest children. The accuracy of 11 year olds and adults was similar. Accessing a property intersection after a class intersection and switching properties were particularly difficult for the youngest children. This may be due to the degree of dampening associated with competing paths. Alternatively, the appropriate nodes may not be in the network.

Insert Table 5 about here

In conclusion, these studies of semantic inference indicate three potential sources of developmental change in relational inference. When similar nodes and links exist, developmental differences are associated

with the efficiency of activation and retrieval processes. There may also be differences in the effects of path activation on the subsequent activation of competing paths. Finally, there are changes in the contents of the network. Each of these contribute to developmental changes in semantic inference.

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Table 1

SAMPLE CLASSIFICATION ITEM

Stem: dog ant robin

Alternatives: 1) paper 2) rock 3) tree 4) frog

Table 2

Accuracy and Latency (sec) Data for Experiment 1

	8	11	Adult
Class rules			
Accuracy	.77	.87	.86
Latency	3.72	2.52	1.88
Property rules			
Accuracy	.76	.79	.86
Latency	5.56	3.63	2.53

Within Class Comparisons for 8 year olds:

Animals (3.28) < Plants (4.38)
Naturally Occurring (3.09) < Manmade (4.12)

Within Property Comparisons for 8 year olds:

Function (4.77) < Perceptual properties (5.49)

Table 3

Conditions in Experiment 2

Item Types	Sample		
	Pair		Triplet
No Revision			
Class-Class	apple	toast	lemon
Property-Property	wheel	sun	penny
Revision necessary			
Class-Higher Class	salmon	bass	deer
Class-Property	apple	orange	ball
Property-Different Property	tack	pin	ant

Table 4

Latency Data (sec) for Experiment 2

Pair Latency	8	11	Adults
Class rules	2.92	1.95	1.63
Property rules	3.86	2.53	1.98
Triple Latency			
No Revision	2.67	1.68	1.5
Revision	3.77	2.97	2.5

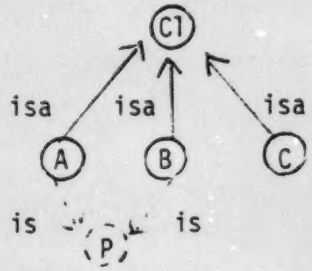
Table 5

Accuracy Data for Revision Items in Experiment 2

Accuracy on Triplet	8	11	Adults
Class-Higher Class	.34	.47	.66
Class-Property	.59	.74	.79
Property-Different Property	.44	.65	.66

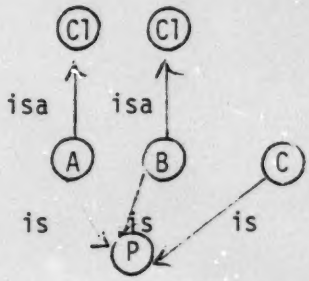
Figure 1

Class - Class



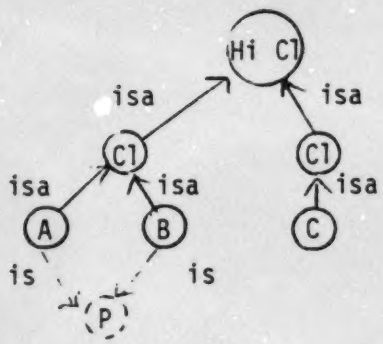
8	11	Adults
2.45	1.64	1.54

Property - Property



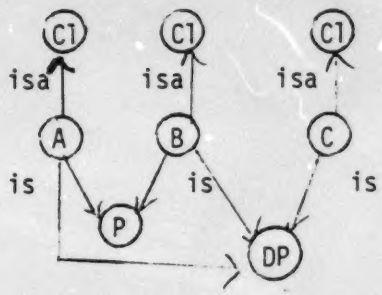
8	11	Adults
2.9	1.72	1.45

Class - Higher Class



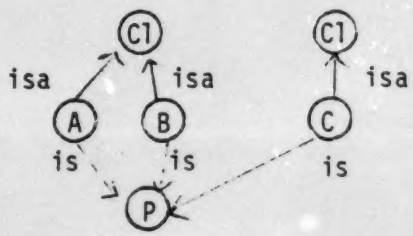
8	11	Adults
3.45	2.33	2.25

Property - Different Property



8	11	Adults
4.36	3.65	3.18

Class - Property



8	11	Adults
3.51	2.93	2.07